Evaluation of Bio-available Aluminum in Water and Sediment of Ajiwa Dam, Katsina State

Okunola O. Joshua¹, Adewusi S. Gbolahan² and Ezeanyanaso C. Scholastica ³

Abstract

Due to indiscriminate disposal of metals in contributory sources of water to the dam, the study investigated the levels of Aluminum (Al) concentrations in untreated and treated water, and sediment of Ajiwa dam. Composite samples of untreated and treated water, and sediment were collected from the dam. Five water and three sediment samples were collected from Ajiwa water works and dam, respectively in October, 2016. Both water and sediment samples were subjected to standard chemical fractionation methods and concentration of Al determined using Inductive Couple Plasma Atomic Emission Spectroscopy (ICP-AES). The results of Al in different water fractions showed; 28.82 – 30.99 mg/L and BDL in dissolved fraction, 3.73 – 5.50 mg/L and 0.57 – 1.76 mg/L in mobile fraction, 23.42 – 27.68 mg/L and BDL in particulate fraction, 2.96 – 5.40 mg/L and 1.23 – 2.26 mg/L in Total fraction for untreated and treated water samples, respectively. The distribution pattern of Al in different fractions was in the order; Carbonate bound (77.20 – 127.30 µg/g) > Residual (49.96 – 41.66 µg/g) > water-soluble (0.54 – 57.11 µg/g) > reducible (9.17 – 13.13 µg/g) > oxidizable (0.42 – 0.49 µg/g) > exchangeable (0.04 – 0.25 µg/g). Generally, the concentrations of Al in both samples are above the World Health Organization (WHO) and United States Environmental Protection Agency (USEPA) maximum recommended limit for drinking water and sediment, respectively.

Keywords: Chemical Fraction, Aluminum, Water, Sediment, Ajiwa

Introduction

Water and sediment plays essential role in the dynamics of the hydrological system. Among both environmental samples, sediment has been reported for ecological and economic values. It provides the habitat and food resources for many benthic and demersal organisms and, through close interaction with the overlying water it forms the basis of the aquatic ecosystem (Belzunce, 2004). The differences between the water and sediment characteristics are described by degree of accumulation, which water showed the real time property of the system that are washed away due to dynamic cleansing of the water system, while sediment showed the history of contamination of the system. Hence, dams as a body of water used for irrigation, generation of electricity, recreational activities and drinking have these properties. These activities with other natural processes release inorganic pollutant such as heavy metals into the dam. Hence, both point (communal and industrial waste water) and diffuse sources (agriculture, atmospheric deposition) discharge heavy metals into the dam (Crane et al., 2001). Ajiwa dam is one of the major dams in Katsina State that is use for irrigation and water supplies to Katsina Metropolis and environs. Previous studies on the dam, reported total concentrations of heavy metals were below toxic limits for drinking water and placed Ajiwa dam within “good” sediment levels for Al, Cd, Cu, and Pb (Suleiman and Audu, 2013).
This study however did not provide insight into the bio-available forms of these metals and data on comparison of the metal concentration from the treated water was lacking. Hence, further research was necessary for to determine the bio-available form of the metals in order to ascertain their toxicity. Therefore, this study is aimed to determine the bio-available form of Aluminum (Al) in the sediment and untreated and treated water of Ajiwa Dam. This is important since Al has been reported to be a major factor responsible for the demise of biotic communities (Charles, 1991; Last and Watling, 1991; Gensemer and Playle, 1999; Kluczka et al., 2012). Hence, evaluating the risk of Al to aquatic organisms requires speciation analysis of Al both in water and sediment (Bezak-Mazur and Widlak, 2004).

Materials and Methods

- Chemicals and Reagents
  Magnesium nitrate (Mg(NO₃)₂), Hydrofluoric acid (HF), distilled water, Hydrogen peroxide (H₂O₂), Na-EDTA, Ammonium acetate (CH₃COONH₄), Hydroxylamine hydrochloride (NH₂OH.HCl), perchloric acid (HClO₄), Sodium chloride (NaCl), Ammonium chloride (NH₄Cl), Hydrochloric acid (HCl) and Nitric Acid (HNO₃). All reagents used are analytical grades.

- Sampling site and sample collection
  The study site was the Ajiwa Dam in Katsina state Nigeria. It is part of Tagwai downstream irrigated land within which the largest farmland acreage of Katsina state are found. The samples; sediment and water were collected from the dam immediately after rainy season in the month of October, 2016. For the sediment, the dam was divided into three sampling sites (SN, SW and SE). A total of nine (9) samples were collected from three (3) sampling sites with the aid of a stainless bottom grab. The content of the grab was emptied into a black polythene bag at each location. Samples were immediately transported to the laboratory where loose particles and plants debris were removed manually by hand picking the debris from the sediment prior to chemical treatment. Each sampling site comprises of three (3) samples were composites to form a core for the site. Surface water samples were collected from upstream (western part of the dam) and downstream (eastern part of the dam) areas of the dam. Western part is the site where irrigation activities are taking place and the eastern part are mainly the channels that water flow into the dams from different tributaries. A total of fifteen (15) surface water samples were collected from five (5) sampling sites, two sampling sites (A and B) from the dam, one (C) from the raw water that has been screen into the treatment sites, one (D) from the treated water tanks and the other one (E) from Marabar Ajiwa giving a total of five sampling points. Three samples were collected from each sampling site; these were pooled together to form a sample for a sampling site. The water samples collected were stored in clean polythene bottles prewashed with 10% Nitric acid and rinsed thoroughly with deionized water. Once collected, the samples were immediately stored on ice in an ice box and transported to the laboratory for analysis.

- Pre-treatment and sequential extraction of sediment and water samples
  Sediment samples for metal analysis were allowed to defrost and then allowed to air-dry. The textures of the dry sediments were determined for each site. Dry sediments were ground into fine powder and homogenized using an acid-washed clean mortar and pestle and sieved to give 200 µm particle sizes. They were then stored in desiccators to attain constant weight before being stored in air-tight plastic bottles. All metallic determination from sediment samples was based on the fine particles obtained. The determination of Aluminum (Al) distribution in the sediment was carried according to Salbu et al. (1998).

  Chemical fractionation of water samples was carried out on the principle proposed by Bäckström et al. (2003). The samples were fractionated into dissolved, mobile, total and particulate. Analysis of Al was performed on Inductive couple plasma - atomic emission spectrophotometer (4200 MP-AES, Agilent Technologies). The validation of the procedure for metal determination and efficiency of ICP-AES was conducted by spiking a sample with solution containing 0.5 mg/L of Al. Quality control was certified by the use of procedural blanks and spikes. The spike recovery for Al was >96 %. All samples were run in triplicates.

- Analysis of Data
  Statistical data analyses were done using SPSS version 17 (SPSS Inc. Chicago, IL, USA). All means recorded were determined at 95% confidence level.

Results and Discussion

- Fractions of Aluminum (Al) in sediment
  The result of Al fractions in the sediment as shown in Fig. 1 indicated that water soluble, exchangeable, carbonate, reducible and oxidizable fractions ranges from 0.536 µg/g (SE) - 57.108 µg/g (SN), 0.035 µg/g (SN) - 0.250 µg/g (SE), 77.201 µg/g (SW) - 127.30 µg/g (SE), 9.1655 µg/g (SE) - 13.128 µg/g (SW), 0.4181 µg/g (SE) - 0.4948 µg/g (SW) and 61.656 µg/g (SN) - 49.960 µg/g
(SW). The fractionation of Aluminum as shown in Fig. 1 suggests that a major portion of Aluminum is bound to the carbonate fraction with a moderate amount associated with exchangeable and organic fractions. This is contrary to report of Nasr et al. (2018), that majority of Aluminum is enriched in the residual fractions. The high concentration of Al in carbonate fraction may suggest anthropogenic contribution of the metal in the exchangeable fraction and the fraction dissolved with acetic acid in the carbonates fraction (Singh et al., 2005). Nevertheless, metals in reducible fractions can be relatively more sensitive to environmental changes unlike metals in residual fraction, which are often unreactive with respect to metal dynamics scale (Horsfall and Spiff, 2005; Ma and Rao, 1997; Akinyemi et al., 2012). This could explain the reason for relatively low concentration of Aluminum in the reducible fractions compare to other literature reports (Turner, 2000; Nasr et al., 2018). Aluminum is found to be in much more higher concentration in the entire fraction, with the concentration exceeding the recommended level of aluminum in sediment (WHO, 1999). Aluminum been the most abundance metal in the earth crust, but it is not an essential element for either plant or human. Hence, availability of aluminum in Ajiwa dam may be attributed to the use of aluminum to lower the pH of the soils used for growing garden egg along the bank of the Ajiwa dam.

![Figure 1: Concentration of Al in sediment fractions](image)

Table 1: Mean(±SD) concentration (mgL⁻¹) of Al fraction in untreated and treated water

<table>
<thead>
<tr>
<th>Fractions</th>
<th>SITES</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved</td>
<td></td>
<td>28.818±0.823</td>
<td>30.433±1.456</td>
<td>30.986±0.931</td>
<td>BDL</td>
<td>BDL</td>
</tr>
<tr>
<td>Mobile</td>
<td></td>
<td>3.816±0.070</td>
<td>5.496±0.976</td>
<td>3.730±0.923</td>
<td>0.566±0.176</td>
<td>1.762±0.708</td>
</tr>
<tr>
<td>Particulate</td>
<td></td>
<td>23.421±1.260</td>
<td>27.472±0.176</td>
<td>27.681±0.106</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5.397±1.2740</td>
<td>2.9608±0.0310</td>
<td>3.305±1.087</td>
<td>1.226±0.421</td>
<td>2.262±2.089</td>
</tr>
</tbody>
</table>

BDL: Below Detection Limits; ND: Not Detected
Fractions of Aluminum (Al) in water

The concentration of Aluminum (Al) fractions in the water samples is presented in Table 1 above.

From the results, fraction of Al was found to be in dissolved and particulate fractions compared to other fractions (mobile and total fractions). The samples from sites A, B and C (raw water from the dam) are more concentrated than those in the site D and E (treated water). The high concentration of the raw water samples (site A, B and C) may be attributed to the use of aluminum to lower the pH of the soils used for growing garden egg along the bank of the Ajiwa dam. Also the higher concentration from the treated water samples (site D and E) may be attributed to the residual Al used in water treatment of Ajiwa water treatment plant (Van Benschoten and Edzwald, 1990). Hence, Al in all the fractions is above recommended standard limit (WHO, 1999; NSDQ, 2007).

Conclusion

The result of the sequential extraction of Al showed that Al was majorly in carbonate fractions a non-residual fraction indicating mobility in the core sediment. The profile of Al bound to the six fractions is: carbonate > residual > water soluble > reducible > oxidizable > exchangeable. For the water samples, the results, showed fraction of Al higher in dissolved and particulate fractions compared to other fractions (mobile and total fractions). The availability of Al in the dissolved fractions indicated toxicity to the dam especially the human through the food chain.

Conflicts of Interest

The authors declare to conflicts of Interest

Funding

No funding was received for this work

References


